Real Time Predictions of the Convective Activity in The Labrador Sea

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LONG-TERM GOALS

This effort contributes to a better understanding of the deep convective process in the ocean. In particular we are interested to evaluate the skills of a prediction system based on real time data in combination with ocean models to forecast the deep convective activity in a given region from a few weeks up to a few month in advance. More recently we realized that one of the critical parameter is the representation of lateral fluxes due to mesoscale eddies. We have completed a study to quantify the climatological mean lateral eddy fluxes.

OBJECTIVES

- Apply and evaluate and improve, in real time, a minimum prediction system to forecast the convective activity several weeks in advance.
- Assess the relative importance of one-dimensional mixing physics versus lateral effects due to mesoscale eddies or other variable flows.
- Quantify the strength of the eddy induced property transfer.

APPROACH

We build on our analysis of the historical data for the Labrador Sea region, which include climatologies of oceanic and atmospheric data as well as individual ocean station data and results from pilot experiments during the winter 1994/95. We have separated the typical mean seasonal cycle from interannual variability for the region. These data sets are used to determine a regional buoyancy budget.

This revised climatology was then used to asses the lateral eddy induced fluxes by diagnosing the subsurface tendency in the density field of mean seasonal cycle.

We also use more complete ocean general circulation models (LOAM) to simulate the situation in the Labrador Sea during the convective seasons of 1996-1998. The model is run a two different resolution, coarse (100-200 km) and intermediate resolution (~25 km) and forced by monthly or daily atmospheric fields. The initial conditions were either the climatology of a longer model run, or the objectively analyzed observations from October 1996.

WORK COMPLETED

We have completed several studies using a two dynamical radial symmetric model for the Labrador Sea and diagnosed its seasonal cycle and tracer transports. The most salient results are part of S. Khatiwala's thesis to be defended in November 1999.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Real Time Predictions of the Convective Activity in The Labrador Sea**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Columbia University,Lamont-Doherty Earth Observatory,Palisades,NY,10964**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

A three dimensional primitive equation ocean model for the North Atlantic was successfully set up and we have preformed many different sensitivity studies. The high resolution version caused more problems than originally anticipated and we are still working on an optimal stetting using different parameter choices, initial conditions and surface forcing data sets.

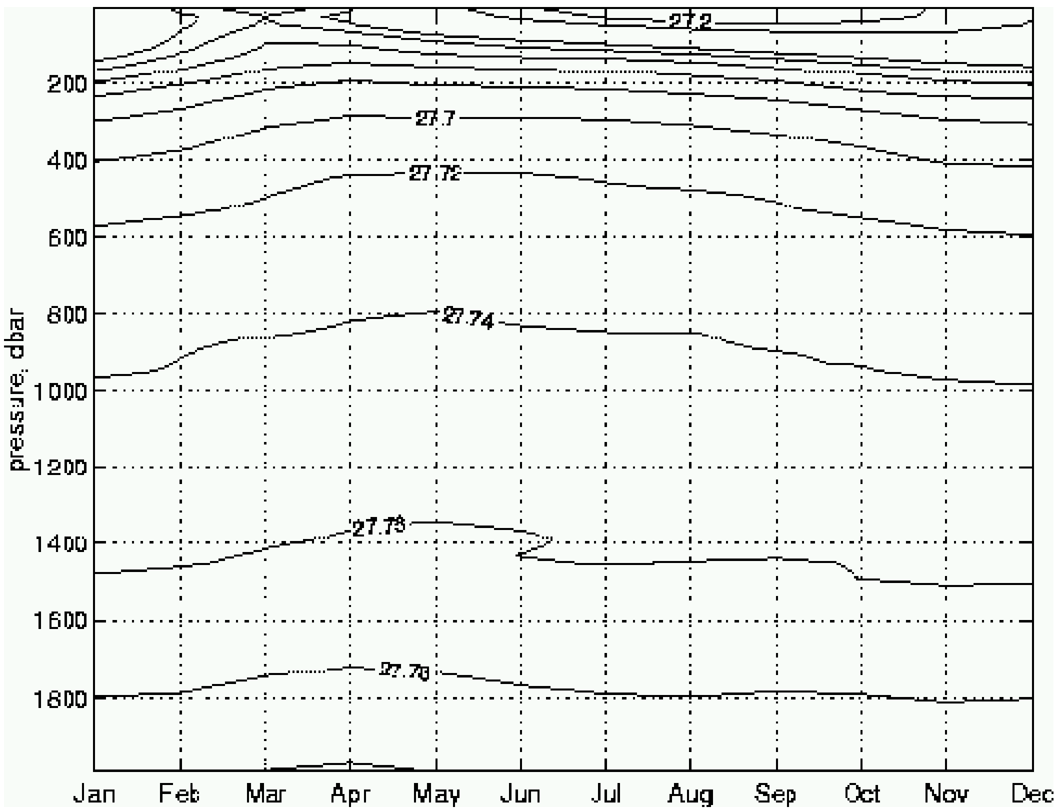
In collaboration with Bob Houghton we have begun to investigate the interannual variability in the Labrador Sea with special emphasis on the convective process and its modulation by fresh water anomalies.

RESULTS

After performing the real time predictions during two winter seasons we have learned a number of lessons. For example it became clear that a significant part of the uncertainty stems from the unknown atmospheric conditions. A correlation analysis showed that much of the monthly and interannual heat flux variability in the central Labrador Sea is linked to the North Atlantic Oscillation (NAO). Therefore, we systematically investigated the response of the North Atlantic Ocean to NAO forcing and published some of the early results (Visbeck et al. 1998). A more detailed investigation of the response in the Labrador Sea in underway and will be submitted for publication later this year. We are currently quantifying the skill of the applied prediction system for different hindcast scenarios.

As part of this process we have completed a study that inspects the climatological mean seasonal cycle in order to infer the strength of the eddy induced diapycnal circulation. This 'overturning' circulation is driven by the slumping of isopycnals and consists of a surface intensified flow transporting low salinity water from the boundary currents into the interior; sinking motion in the central Labrador Sea; and an 'outflow' at depth transporting newly ventilated Labrador Sea water towards the boundaries. Typical eddy-induced velocities are estimated to be roughly 0.5 cm/s for the surface inflow, 1 m/day for the vertical motion, and 0.1 cm/s for the deeper outflow, in surprisingly good agreement with those calculated in a simple numerical model of the Labrador Sea. The outflow velocity corresponds to a ventilation time scale of 3 years, similar to idealized age tracers simulated in the model.

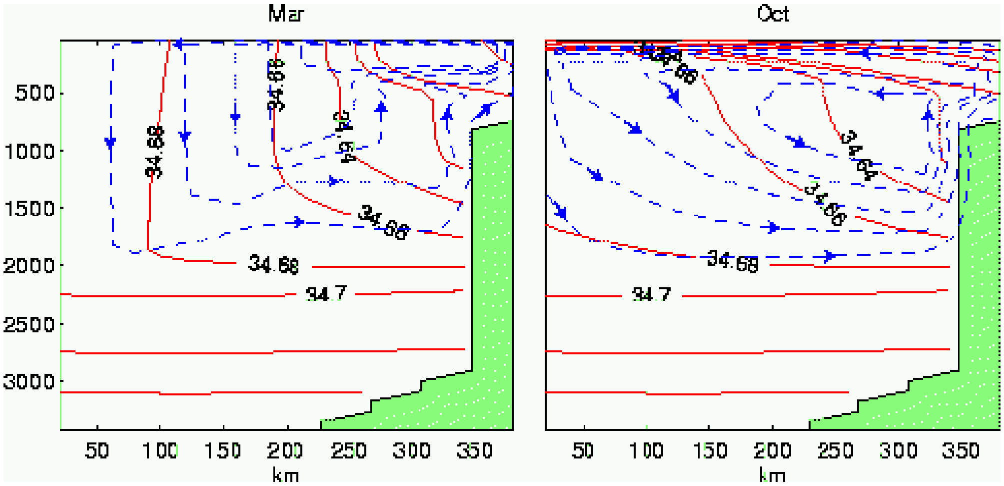
These calculations were based on climatological data set for the mean annual cycle of density in the central Labrador Sea for the 1964--1974 period. (Fig. 1). In the upper 1000 m isopycnals drop by about 200 m over a period of 7 months (April to November), implying an eddy induced vertical velocity w* of -10^{-3} cm/s or 1 m per day. Data from individual years give similar values for w*. Note, that the climatology is based on a period of relatively weak convection and the overturning circulation is restricted to the upper 1000 m. The corresponding horizonal flows can be inferred from the continuity equation.



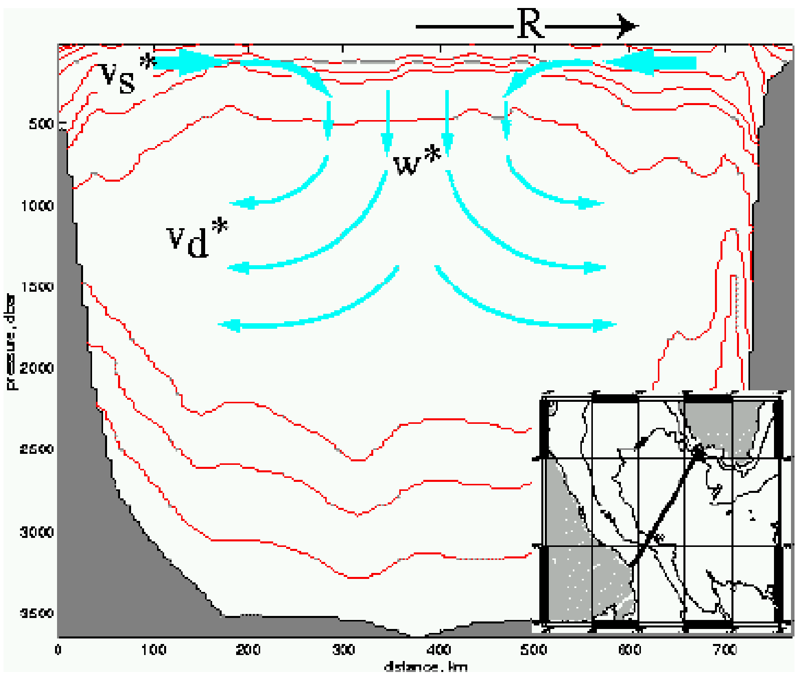
1. Mean seasonal cycle of potential density for the central Labrador Sea.

For comparison, the convective regime of the Labrador Sea has been simulated in a two-dimensional ocean model (Visbeck et al., 1997) coupled to an atmospheric mixed layer model, and configured for an azimuthally averaged domain to crudely represent a radial section across the Labrador Sea. The eddy-induced velocity is parameterized using a isopycnal thickness diffusion with a constant diffusivity of 400 m^2/s. Fig. (2) shows the time evolution of potential density (solid) and the overturning streamfunction (dashed) representing the eddy-induced velocity field over the course of the seasonal cycle. The modeled circulation bears a strong resemblance to the schematic shown in Fig (3) as well as to the observed evolution of the density field.

An eddy induced inward flow of 0.3 cm/s over upper 300m depth would yield an annual mean warming equivalent to an annual mean 50 W/m^2 heat loss at the surface. Those numbers are very similar to the annual mean air-sea fluxed as observed in the central Labrador Sea (see Lilly et al., 1999, for a recent discussion).



2: Density field (solid) and eddy induced stream function for a 2D (depth-radius) ocean model applied to the Labrador Sea setting.



3: Schematic of the eddy induced overturning circulation.

IMPACT/APPLICATIONS

This study will help to identify potential problems of dynamical forecast systems in regions of deep mixing activity. It will also give an assessment of state of the art coarse resolution ocean circulation models in regions where deep convection is expected.

TRANSITIONS

We have developed a research mode prediction systems which was not designed to be directly transferred to operational centers. However, the concept can readily be adopted and the identification of major shortcomings as well a potential solution should be beneficial for operational ocean forecast efforts.

RELATED PROJECTS

This project is well connected to many other components of the Accelerated Research Initiative "Deep Convection". We have work with sea going PIs to guide their observational strategies, disseminate information relevant to the group and also provide some generic information about the ARI on the web.

In the more recent works we closely collaborate with Peter Schlosser and his graduate student Samar Khatiwala from Lamont who has interpreted transient tracer data from the Labrador Sea collected over the last 10 years.

REFERENCES

The findings from most of our work can be found on the web under
http://www.ldeo.columbia.edu/~visbeck/labsea

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